Circularly polarised planar antenna excited by coplanar waveguide feedline

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A circular patch antenna fed by a coplanar waveguide (CPW) line is proposed to obtain circular polarisation (CP). The CP results from the combined excitation of the patch by an inclined slot (integrated in the CPW feedline) and the CPW feedline termination. The asymmetrical characteristics of the excitation involve the excitation of both the odd and the even modes in the CPW line.

Introduction: As the feedline and the ground plane are located on the same layer, CPW-fed antennas facilitate the integration of active devices without via hole connections (no backside processing). This feature makes the CPW-fed antenna a good radiating element for radio frequency identification (RFID) systems where the transponder is generally limited to the basic connection of a dedicated integrated circuit to the antenna. In various RFID applications, the relative positions of the transponder and the reader are unknown, which makes the use of CP highly advisable for a correct communication. This Letter presents a circularly polarised CPW-fed antenna dedicated to RFID applications and more specifically to dedicated short range communication (DSRC) at 5.8 GHz.

CP is often generated by geometrical perturbations on a printed element such as asymmetries [1], notches [2] or stubs [3]. These perturbations yield two orthogonal degenerate modes with linear polarisations of equal amplitude and 90° out of phase in a narrow bandwidth. In our work, the CP is obtained by combining two non-orthogonal modes independently excited by an inclined slot and the open termination end of the CPW line (Fig. 1). For this reason, the selected radiating element is a perfectly circular patch, which can generate a linear polarisation in any direction and also permit a symmetrical radiation pattern to be obtained. The correct phase difference and magnitude of the excited modes are obtained by tuning the various available parameters (length L_s of the line extension under the patch, length L_a of the inclined slot, thickness h_1 of the substrate).

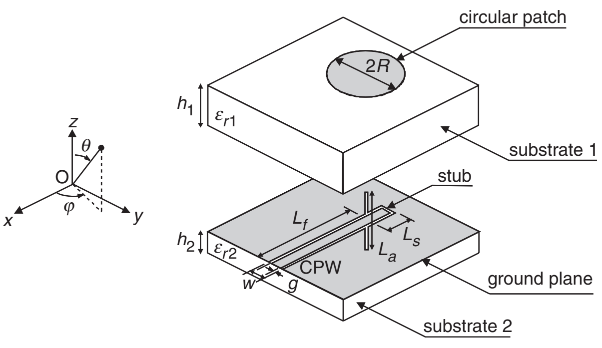

Fig. 1 *Geometry of circularly polarised microstrip antenna*

$\varepsilon_{r1} = 2.2$ (DUROID 5880), $h_1 = 3.175$ mm, $R = 9$ mm, $\varepsilon_{r2} = 4.5$ (TMM4), $h_2 = 1.524$ mm, $w = 3.5$ mm, $g = 0.5$ mm, $L_s = 5.5$ mm, $L_a = 20$ mm, $L_f = 30$ mm

CP basics: It is well known that the superposition of two orthogonal fields $\vec{E}_x$ and $\vec{E}_y$ given by:

$$\vec{E}_x = E_0 e^{j\pi/2} \vec{u}_x \tag{1}$$

$$\vec{E}_y = E_0 \vec{u}_y \tag{2}$$

in their phasor form results in a right-hand CP plane wave defined by:

$$\vec{E} = E_0(\vec{u}_y + j\vec{u}_x)e^{-jkz} \tag{3}$$

Let us now consider two non-orthogonal linear field components $\vec{E}_x$ and $\vec{E}_\xi$ with an angle $\xi = (\widehat{\vec{E}_x, \vec{E}_\xi})$:

$$\vec{E}_x = E_0 e^{j\phi} \vec{u}_x \tag{4}$$

$$\vec{E}_\xi = E_0 \vec{u}_\xi \tag{5}$$

To obtain a CP plane wave, it can be easily shown that the electrical phase ϕ must comply with:

$$\tan\phi = -\tan\xi \tag{6}$$

In this case, the CP plane wave is given by:

$$\vec{E} = E_0 \sin\xi(\vec{u}_y + j\vec{u}_x)e^{-jkz} \tag{7}$$

Note that, when ξ deviates from $\pi/2$, the amplitude of the radiated field is necessarily smaller than in the optimal $\xi = \pi/2$ case.

Antenna design: The circular radiating patch is printed on the upper side of the first substrate; the ground plane, the CPW feedline and the 45°-inclined coupling slot are on the upper side of the second substrate. The relative permittivities and substrate thicknesses are $\varepsilon_{r1} = 2.2$, $\varepsilon_{r2} = 4.5$, $h_1 = 3.175$ mm and $h_2 = 1.524$ mm. ε_{r1} has been chosen small to favour the patch radiation and the coupling between the patch and the slot. ε_{r2} has been chosen high to reduce the size of the CPW feedline compared to the radiating element. The line is dimensioned using [4] for a 50 Ω characteristic impedance ($w = 3.5$ mm and $g = 0.5$ mm). The circular patch (radius $R = 9$ mm) is dimensioned using the cavity method [5] to resonate at 5.8 GHz.

The coupling slot, whose dimensions are given on Fig. 1, is centred below the patch with a −45° inclination angle with respect to the x-axis. The electromagnetic energy is coupled from the CPW feedline to the circular patch through the coupling slot.

The use of a coupling slot integrated in the CPW feedline allows the appearance of two near-degenerate modes and right-hand circular polarisation (RHCP) radiation. Left-hand circular polarisation (LHCP) radiation can be obtained when a +45° rotation angle is applied to the inclined cross-coupling slot.

Simulations and experimental results: The dimensions of the RHCP microstrip antenna have been optimised with the 2.5D commercial software Ensemble [6] for good matching at 5.8 GHz. The measured return loss (Γ) is shown in Fig. 2. We observed that the operating frequency is shifted to approximately 6 GHz with Γ = −15 dB. The measured impedance bandwidth (Γ < −10 dB) is about 3.6%. The first resonance at 5.42 GHz corresponds to one of the two linear modes required to generate CP.

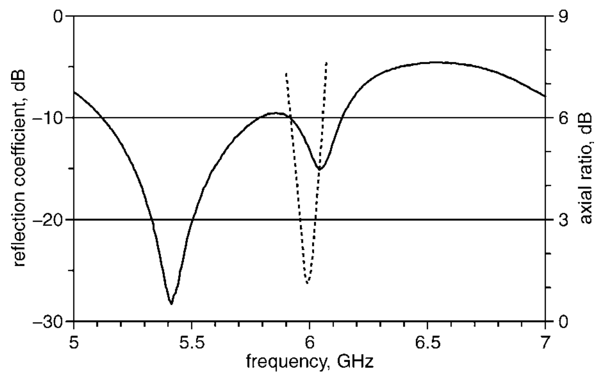

Fig. 2 *Measured reflection coefficient and axial ratio against frequency*

—— reflection coefficient
- - - - axial ratio

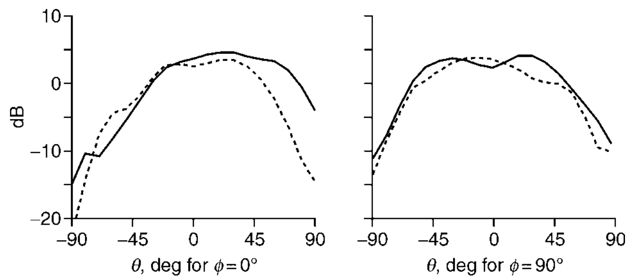

Fig. 3 *Measured radiation patterns at 5.99 GHz*

—— E_θ
- - - - E_φ

The measured axial ratio (AR) is shown in Fig. 2. The RHCP bandwidth, determined for AR < 3 dB, is 63 MHz (~1%). The minimum AR is 1.1 dB at 5.99 GHz for a 5.9 dB gain. The measured radiation pattern at 5.99 GHz is shown in Fig. 3 and a 3 dB AR aperture angle of $\Delta\theta = 45^\circ$ has been measured in both planes around the z-axis.

Conclusions: A new compact CPW feed design for circularly polarised microstrip antennas has been proposed. It is based on the proper tuning of two coupling discontinuities (inclined slot and CPW end) in the feeding line. The Γ and AR bandwidth match most RFID requirements and the AR beamwidth is larger than in CP antennas based on geometrical perturbations. The large CP beamwidth makes the antenna a good candidate for identification applications.

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